

# 1

## *Accidents: General Principles*

### **1.1 Why Accidents Occur**

**A**ccidents are unexpected, unplanned events that result in harm or loss to personnel, property, production, or nearly anything that has some inherent value (i.e., targets). These losses increase an organization's operating costs through higher production costs, decreased efficiency, and the long-term effects of decreased employee morale and unfavorable public opinion.

Accidents are rarely simple and almost never result from a single cause. Usually many factors that tend to develop in sequence over time contribute to the causes of accidents. These factors may be interrelated and may include one or more of the following:

- Human capabilities
- Equipment design
- Environment.

Accidents can occur whenever significant deficiencies, oversights, errors, omissions, or unanticipated changes are present. Any one of these conditions can be a precursor for an accident; the only uncertainties are when the accident will occur and how severe its consequences will be.

By understanding these factors, management can put barriers and controls in place to prevent an accident or mitigate its consequences. Barriers to protect targets against loss can be **physical barriers** such as machine guards and railings, **administrative barriers** such as procedures and policies, and **supervisory or management barriers** such

as work instructions, line management oversight, and communications. In a work environment, several levels of barriers may be used in an effort to prevent accidents. Accidents occur when one or more barriers in a work system, including procedures, standards, and requirements intended to control the actions of workers, fail to perform as intended. The barriers may not exist, may not be adhered to, or simply may not be comprehensive enough to be effective. Personal performance and environmental factors may also reduce protection.

A certain level of risk is inherent in every activity. Accepting some level of risk is necessary, but to protect against unwanted loss (e.g., injury, property damage, production downtime), risks must be controlled, transferred, or eliminated. Understanding how to prevent or control accidents requires an understanding of the sequence of events leading to an accident in order to identify and implement countermeasures that protect against risks.

### **1.2 Human Factors Considerations**

Human factors considerations focus on people and their interaction with equipment, facilities, procedures, and environments in work and daily activities and how these considerations affect accidents. Analyzing human factors provides the investigator with a framework for assessing the role of humans in the workplace. Human factors—fatigue, stress, comfort with equipment, and the like—should be assessed during the data collection process to ensure that they are

considered as part of the overall analysis of an accident. Understanding human factors as they relate to accidents requires knowing how the human-machine interface operates in the workplace, the capabilities people bring to a task, and how the primary elements of the work setting affect human performance.

### 1.2.1 Human-Machine Considerations

In every accident, there is a human consideration, or a human-made object, or both. Generally, any accident can be attributed to a human activity or response. For example, a worker may forget to follow safety procedures when operating equipment. Such an error may be disastrous if it causes an accident, and it would be obvious why the accident occurred: the worker failed to follow safety procedures. In another situation, an accident may occur because equipment malfunctions. In this case, it may not be obvious that the primary cause of the accident is related to human performance (e.g., a poorly constructed control device).

In both examples, the accident can be attributed to some type of human error, and there is more than one single cause of each accident. An investigation of both accidents would involve examining the human activities, the equipment or machine, and the environment.

Figure 1-1 shows the relationship among humans and machines. This relationship provides a framework or “activity model” for examining an accident’s setting, as well as a mechanism to examine many potential causes of the accident.

Before examining factors that may contribute to accidents, it is important to understand the process people use to perform a task or activity. As shown in Figure 1-1, humans perform the following activities to complete a task:

- **Information Perception:** This activity serves as a trigger to perform a task. For example, a driver at a traffic light must perceive that the light changes from red to green before acting to start the car moving. Perceiving information means that the human has detected some type of signal; this may be visual, auditory, tactile, and so on.

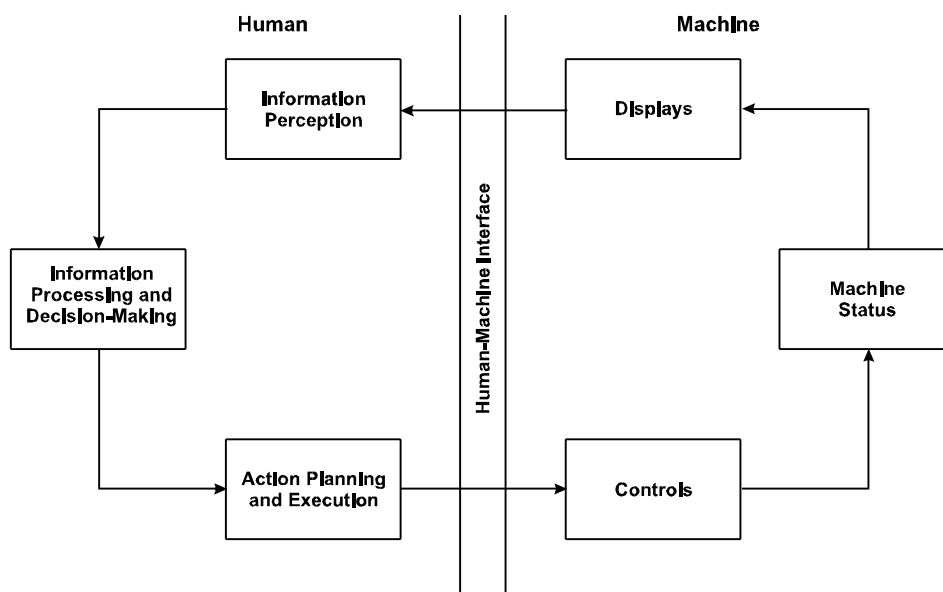


Figure 1-1. Human-machine “activity model.”

- **Information processing and decision-making:** This activity involves processing the information to determine its meaning and the appropriate response. For example, when the traffic signal changes from red to green, the human processes the information from the stimulus and determines that it is possible to go and what action to take. The driver may choose to make a turn, drive forward, or remain stationary.
- **Action planning and execution:** Whichever action is selected, the human then plans a course of action and executes it by performing a response (this generally involves a controlled motor response). In the traffic light example, this may require very little thought by the experienced driver, but may result in some planning by the new driver, who may check the street very thoroughly and check with a passenger to make sure they are going in the correct direction. The driver then proceeds through the intersection (driving the vehicle is a controlled motor response).
- **Feedback:** Often, humans obtain feedback following their actions. Feedback for the driver may involve driving through the intersection. Safe passage indicates that the driver has successfully interpreted the input and acted accordingly. In more complex situations, such as nuclear power plant operations, the process is more complex. For example, an operator may perceive information from an annunciator panel, process its meaning, determine the appropriate action, plan the action, confirm with the senior control room operator, execute the action, and obtain feedback from visual displays and audio annunciators. This process triggers additional perceptual information that reinitiates the entire process.

### 1.2.2 Human Capabilities Considerations

The capabilities humans bring to the work setting have important implications for accidents. These may result from the way work processes, equipment or machines are designed. From the human factors perspective, work settings generally are designed for the “average” human. For example, automobiles in the United States are designed for persons of the U.S. average height; thus, persons who are much shorter than the U.S. average sometimes require special devices to help them reach and operate the controls. Without such controls, these people are more accident-prone in driving situations because their performance is impaired.

Determining whether worker capabilities match work requirements is another human factors consideration. For example, military and commercial aircraft pilots are selected, in part, for their quick response time, problem-solving abilities, and visual acuity. Persons in this occupation who lack high levels of these capabilities have a greater probability for accidents.

Table 1-1 lists human capabilities that contribute to the actions described in the “activity model.” These are only a sample of capabilities that contribute to effective performance. Many other capabilities can affect performance, depending on specific task requirements:

- **Experience, knowledge, and training:** For any task or work activity, human performance is generally enhanced if the person has previous experience in performing the task, has knowledge of the input, and understands the meaning of various indicators and the implications of various actions. This knowledge and experience can be gained through formal training, education, and on-the-job training.

**Table 1-1. The suitability of human capabilities required to perform work activities is an important consideration in analyzing causes of an accident.**

Work Activity	Human Capability	Specific Examples
Information Perception	Perceptual Processes	Vision Hearing Pain
Information Processing and Decision-Making	Cognitive Processes	Short-Term Memory Long-Term Memory Problem Solving
Action Planning and Execution	Motor Processes	Repetitive Movements Tracking Movements Manual Dexterity Muscular Strength Reaction Time

- **Physical aptitude, fitness, and behavior:** A worker's capability to perform effectively may be reduced by: (a) recent injuries or surgery or temporary physical limitations; (b) seasonal allergies or other temporary disorders; (c) changes in visual capacity (e.g., decreased visual acuity due to aging, color vision, and night adaptation) or changes in work that demand greater visual abilities; (d) hearing loss due to noise exposure; and (e) physical and neurological effects due to exposure to toxic materials.
- **Stresses:** Workers may experience stress because of work-related or personal events. Sources of stress may stem from (a) drug use—which can impair motor and cognitive functions—including taking prescription or over-the-counter medications to alleviate a condition or injury (e.g., taking antihistamines for allergies); (b) alcohol consumption, reducing sensory perception and resulting in loss of physical coordination; and (c) smoking, which can cause muscular deterioration and weakness.
- **Fatigue:** This may result from an excessive workload for an extended period.
- **Work shift changes:** Changes in working hours (from day to evening) can alter a worker's effectiveness until he/she has adjusted to the change in schedule.

### 1.2.3 Equipment Design Considerations

The design of machines and equipment can also be a causal factor in accidents. Equipment design features should be evaluated during an accident investigation in terms of the human-machine interaction characteristics shown in Table 1-2.

A review of equipment design features can provide information about potential sources of human error. For example, if control locations or operations are incompatible with widely accepted norms, an error in operation is likely. Thus, if an accident involves some type of equipment, it is useful to examine the equipment and its operational features to determine whether the design is incompatible with human

**Table 1-2. Equipment design can affect human performance.**

<b>F</b> eatures	<b>I</b> nteraction Characteristics
Gross Equipment	<ul style="list-style-type: none"> <li>■ Equipment to carry or house humans should be designed with specified size, stature, and sitting height limitations.</li> <li>■ A proper field of view should be provided.</li> </ul>
Control Placement and Operations	<ul style="list-style-type: none"> <li>■ Control knobs and dials should be positioned so that an operator can easily reach and operate them.</li> <li>■ Controls should be placed in an arrangement that logically reflects the normal sequence of operations.</li> <li>■ Control operation should be compatible with widely accepted standards or norms (e.g., knobs turn clockwise to increase power and counterclockwise to decrease power).</li> </ul>
V isual Displays	<ul style="list-style-type: none"> <li>■ I nformation presented in visual displays should be easy to perceive, process, and interpret.</li> <li>■ Coded information should be compatible with widely accepted standards or norms (e.g., color-coded indicators, such as red for danger, yellow for caution).</li> </ul>
A udio I ndicators	<ul style="list-style-type: none"> <li>■ A udio alarms should be easily interpreted and distinguishable from other audio indicators.</li> <li>■ A udio alarms should be compatible with widely accepted standards or norms, so that high frequency and rates indicate urgency.</li> </ul>

performance. Equipment manufacturers generally provide operations and maintenance technical manuals to ensure effective operations. Accident investigations involving equipment should include a review of the equipment's technical manuals, which may be helpful in identifying inadequacies in operating procedures or equipment maintenance.

### 1.2.4 Environmental Considerations

The environment can also influence human and machine performance, thereby contributing to the causes of an accident. The work environment can be defined at several different levels. For example, the immediate work environment is the setting in which the accident occurred. Broader levels of the environment, including the general characteristics of an organization, can also affect performance and contribute to accidents.

#### 1.2.4.1 Immediate Work Environment

Many immediate work environment factors and the associated requirements are specified in Occupational Safety and Health Administration (OSHA) regulations. Physical

environmental factors that may influence the effective performance of both humans and equipment include:

- ***Illumination:*** The level of lighting must be sufficient for workers to have a good view of their work environment, the equipment, and the materials they are working with.
- ***Noise:*** High levels of noise can distract workers from concentrating on the task they are performing. In addition, high levels of extraneous noise can interfere with audio indicators that workers rely on to signal actions or activities.
- ***Vibration and motion:*** High levels of vibration and motion can interfere with human task performance, especially tasks that require fine motor movement. Vibration can also interfere with equipment performance, causing unexpected performance decrements in equipment that is normally considered highly reliable.
- ***Thermal conditions:*** Worker performance is influenced by temperature extremes, which can often influence worker concentration (information processing and decision-making).

Extreme temperatures may also affect human control responses by requiring additional clothing or gear for protection. In addition, equipment may have limited operating conditions under extreme temperatures. Therefore, it is important to identify the limits of equipment and machines under extreme temperatures.

- ***Altitude and depth:*** Humans can experience physical functioning problems when performing at high altitudes and extreme depths; in general, they also experience cognitive functioning decrements under both these conditions.

Humans and equipment are limited in their capacity to perform effectively under extreme or unusual environmental conditions. When investigating an accident, it is important to characterize the environmental conditions at the time of the accident and the potential human or machine performance decrements that could result.

#### ***1.2.4.2 Broad Environmental Factors***

Environmental factors not directly apparent in a work setting can also contribute to ineffective performance or accidents. These factors usually correspond to work conditions established by the organization. Examples include:

- ***Organizational climate and culture:*** These components describe how employees and managers generally approach their jobs. For example, an organizational policy may emphasize safety as a key component of job performance. However, in reality, managers and employees may not perform according to policy because of problems or miscommunications in implementing the policy. Management

expectations and interest also affect how employees perform their jobs.

- ***Work schedules and staffing:*** Organizational practices can influence employees' effectiveness. Practices such as failing to provide sufficient numbers of staff to work on a job (increasing workload) and frequently altering work shifts of employees (increasing fatigue) can ultimately lead to errors in human performance.
- ***Internal and external communications:*** For organizations and humans to operate effectively, information about work performance and conditions must be communicated clearly and consistently. Upper management may have the best intentions for implementing safe work practices; however, if these intentions are not clearly communicated and translated into work practices, workers will not follow them. Communication problems appear in many forms and extend from one management level to the next, from managers to workers, from safety policies to actual work practices, and so on.
- ***Worker selection and training:*** For any job or task, it is important to identify workers with the abilities required to perform the job effectively. Workers must also be adequately trained in job performance, safety procedures, and equipment operations. Performance can be adversely impacted if adequate training is not provided or if a worker does not gain the necessary knowledge and skills from training. Thus, during an accident investigation, it is important to examine procedures for evaluating training effectiveness in order to determine whether these factors may have contributed to the accident.

## KEY POINTS TO REMEMBER

**A**ccidents are unwanted and unintentional events that result in harm or loss to personnel, property, production, or anything that has some value. Barriers (physical, administrative, and management) should exist to prevent accidents or mitigate their consequences. Accidents occur when one or more barriers in a work system fail to perform or do not exist.

Human factors are important in assessing the causes of accidents. Two basic principles are important in assessing the role of human factors in an accident:

- Nearly every accident has more than one cause.
- Human error can be identified as a causal factor in nearly every accident.

The major human attributes that affect work performance are:

- Experience, knowledge, and training
- Stresses
- Work shift changes
- Physical aptitude, fitness, and behavior
- Fatigue.

In conducting the investigation, it is helpful to consider three factors and how these might have influenced or caused the accident. All three should be evaluated during data analysis:

- **Human capabilities:** These involve the worker or person directly involved in the accident.
- **Equipment/machine errors:** These involve equipment malfunctions or design problems that contribute directly to human error. Humans also contribute to equipment failures by means such as contributing to design flaws, failing to maintain equipment, and failing to use equipment safely and properly. The human-machine interface is also an important consideration.
- **Environment:** This includes the immediate environmental conditions, such as extreme temperatures, poor illumination, and distracting noises and vibrations. Broader environmental contributors to errors may include management systems that fail to protect workers from extreme conditions or fail to provide safe operating procedures, work schedules and staffing inefficiencies, communications failures, and inadequate worker selection and training.